INNOVATION IN THE PROCESS OF TILE DECORATION

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ILLUSTRATIONS

BOARDS

1. INTRODUCTION

This present research prevents to analyze an important innovation in the ceramic field in Spain, especially in the innovation which has been developed in Castellón and has allowed the regional cluster to entry into new markets, named Inkjet or ink stream, this technology is placed in the production process in the ceramic tiles, this technology in the ceramic decoration stage, these printers has been implemented all around the world to decorating tiles.

This research departs from a theoretical frame about innovation, where innovation will be explained, the different types of innovation in the business field that exist, classifying innovation as incremental or radical which among other benefits allow to entry into new markets and finally the different processes or ways that develop an innovation.

Next, the history of ceramics and its evolution will be explained, the different innovation techniques which have existed throughout history will be detailed, as one of the first techniques known in the world of the ceramics is the warping thanks to which the shape of the ceramic was obtained. The history explained goes from 6000 BC to the 12th Century.

Then, the manufacturing process of the ceramic tiles is explained step by step, it starts with the extraction of the materials, following the preparation and mixture of raw material, after that the moulding/ shaping of the products, the following step is the drying of the products, then the topic which will be analyzed in a more detailed way in this part, is the superficial treatment and the decoration of the ceramic products, finally the cooking of these ceramic products.

Forwards, the way the ceramic industry is formed will be analyzed, in all the countries where the ceramic industry has an importance the sector is organized in a consolidated cluster, which generates a big cohesion between the companies and the institutions, in those countries.

Following with the analyses of the cluster, the cluster which exist in Castellón will be analyzed, where most of the ceramic industry in Spain is concentrated, this cluster will be detailed because it has an important innovative process for the ceramic industry and it is where the inkjet technology for ceramics was developed.

One of the last sections will be dedicated to the economic analysis of the ceramic industry in Spain, to explained how the ceramic industry managed the time of crisis,

how it has left the Spanish crisis behind and how it is progressing in the last years relying on official data.

Finally the inkjet technology will be explained, this technology exists in different fields, its main use is in printing paper.

Then the way the inkjet technology was developed in the process of the decoration of ceramic tiles will be explained.

Ultimately, the way the ink stream works and the two types which exixt will be explained, the continuous stream and the drop on demand, which are the processes that are used by the inkjet technology in the decoration of ceramic tiles.

In essence, the present research intends to show the different innovations that have appeared in the world of ceramics and the last radical innovation of processes which has been launched to the world of the manufacturing of tiles which is the inkjet technology and which was meant a revolution in the ceramic industry.

2. INNOVATION THEORETICAL FRAMEWORK

First of all and before explaining a definition of the word innovation, it must be understood why businesses invest their resources, time, money and people in innovating, the fist element which shows that an innovation has taken place is that it provides a benefit to the company, this benefit must usually be an economic one. Secondly, because of the competitiveness among the different companies, there are two types of them: the offensive companies which are innovative and the defensive companies which do no invest. Finally, according to Drucker “any new product, process or service is becoming obsolete the moment it generates benefits”, meaning that the moment a company has innovated must be preparing the way for the next innovation.

As Valls and Esorsa (1998) mention innovating is a synonym of changing. The company which wants to innovate is in constant change, progress, developing new things, constantly offering new products and improving new manufacturing processes.

The OECD Oslo manual (Oslo, 2005) 77, states that the companies use their incomes to investigate and develop an innovation, so that they can improve their results, either increasing the product demand or reducing the production costs. For example a product or process can place a company in a vantage point in the market. When the company achieves an innovation in the process it profits because it reduces costs compared to its competitors, getting a higher profit margin, being able to set lower

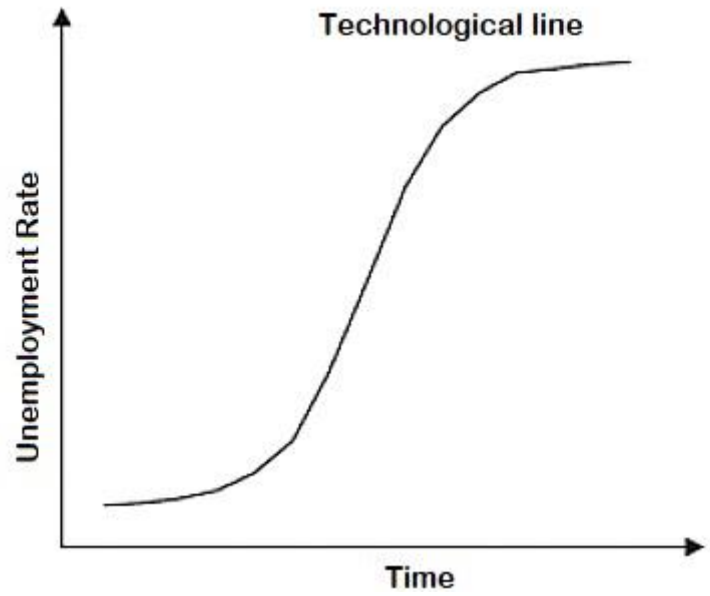
prices and having benefits. Referring to a product innovation, the company gets benefit launching this new product into the market, being able to increase the demand and its profit margin.

Valls and Esorsa (1998) highlight that there are three main reasons why a company must keep on innovating. Firstly, because of the technical process, current products can stop existing at any moment since new products appear with better performances. Secondly because of globalization, the competition aggravates not only regionally but between countries. The last factor is the non-mass markets as there is a tendency to produce products according to the consumer characteristics which are more and more personalized ones.

2.1. S-curve

As it has been mentioned before, the process or product cycle is shorter and shorter due to the constant changes in technology, the S-curve relates the spent effort in developing the technology with the obtained results. (Valls and Esorsa, 1998)

Picture 1 S-curve



Source: (Valls and Esorsa, 1998)

The authors (Valls and Esorsa, 1998) state that the S-curve shows the whole process of the investigation, when the process starts it may be slow, but then when the problems are solved and thanks to the investment the performance improve quickly. Thanks to this investment a fast grow can be observed, however, it mayl stabilize and this way the company will do a higher investment than in the previous stage in order to

keep the same rate of growth or it will have to reduce the enhancement level. This happens when the technology is near its limits.

Foster points out that in crisis periods companies with an offensive role are the ones which usually take advantage, they are the companies which take a risk investing in new technology, on the other hand, defensive companies needs more time to deal with technology in that hard time and so they are left behind, according to Foster “innovation is not a deserted process but a battle between attackers and defenses.

2.2. Innovative Activities

As it is mentioned in the 145 paragraph in the Oslo manual (Oslo, 2005), innovative activities include scientific, technological, financial, trade and organizational activities. Some of these activities are innovative other are necessary to introduce the innovation. Depending from the company they can make more defined, detailed and with higher budget innovative projects or with more or less freedom.

According to the Oslo manual (Oslo, 2005) an innovation occurs when it is introduced a new product or the improvement of a new product which may be a good or a service, of a process, of a new commercialisation method, of the workplace organization or of the foreign affairs.

It can be considered that a company is innovative in the case they have introduced an innovation during the research period. Referring to a product or a process, an innovative company is the one which has introduced or has improved significantly, during the research period. (Oslo, 2005)

2.3. Definition of innovation

When referring to innovation we may think that necessarily it must be a discovery, or a brilliant invention which means an exclusive worldwide. We could define innovation as the introduction of a new and significantly improved product, service, process or trade or organizational method. To be considered an innovation it must be at least new or significantly improved.

To be considered a real innovation, the product, process, trade or organizational method must be new for the company or at least they must be significantly improved.

2.4. Types of innovation

As it has been mentioned before there are different types of innovation and we can classify the innovation if it is a product or a service, a process, marketing or organization.

Innovation of a product: introduction of a new good or service or significantly improved. This definition includes the significantly improvement of the technical characteristic of components or materials, of integrated IT, of the usage feasibility or other functional characteristic. The creation of a new product can result in a new technology or it can be the result of different technologies or knowledges which already exist. (EOI, 2007)

Innovation of a process: introduction of a new or significantly improved production or distribution process. To have an innovation in a process there must be important changes in technics, materials and/or working programmes (EOI, 2007)

This type of innovation can bring a reduction in the production costs, a quality improvement or the production of new products or significantly improved. (EOI, 2007)

Innovation in marketing: this innovation refers to a new trading method which involves important changes in the design or in the packaging, the positioning, the promotion and the pricing of a product. (EOI, 2007)

As it is mentioned in (EOI, 2007). This innovation is more focused on satisfying the necessities of the consumers, the opening of new markets or a new positioning of a certain product. To be considered an innovation in marketing it must be referred to the methods which have not been used before and which mean a break with previous practice.

Innovation in the organization: the introduction of a new organizational method in practices, the organization of a work-place or the foreign affairs of the company. The thing which distinguishes an innovation from a change in the company is that it must not have been used before by the company. (EOI, 2007)

2.5. Innovation depending on the method used to obtain the innovation.

In the book EOI (2007) they state that two methods can be used: technological innovations and non-technological innovations. The first refers to a change in a company which has been produced because of the use of technology. This type of innovation is very used in changes related to process in innovation. While the non-technological changes are used in the organizational changes, new systems of production or trading.

This type of innovations are related one in another, we can find that the adoption of a new technology in a company must be accompanied almost necessarily with organizational structures and the redesign of new business processes (EOI, 2007)

2.6. Process of innovation.

As it is highlighted in EOI, 2007 in the process of innovation there is usually a distinction between investigation and development (I+D) and the rest. I+D can be classify into three types: basic or fundamental investigation, applied investigation and development.

Basic investigation refers to those original tasks which have as an objective to acquire new scientific knowledges about observable phenomenons and facts. In this type of investigation properties, structures and relations are studied with the objective of making hypothesis, theories and laws. (EOI, 2007)

According to EOI 2007 an applied investigation is carried out on already existent works with the objective of acquiring new scientific knowledges, focused toward a more practical objective. This type of investigation is closely related with the basic investigation since it uses its results and research on new methods and means in order to reach a specific objective. These results could be distinguished between new products, rage of products, processes and methods.

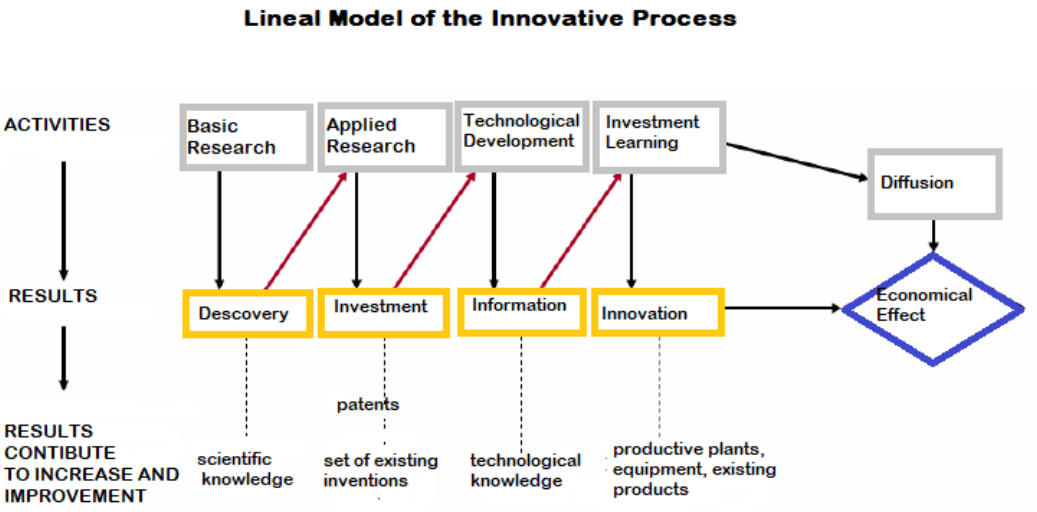
The technological development uses knowledge for the production of new materials, procedures, systems or services or important improvement in them. It is carried out standardized research which is based on previously acquired knowledge which come from the applied investigation or from the experience. The objective of the technological development is to launch into the market a newness or a concrete improvement. (EOI, 2007)

There are different models which explain the innovative process which are adapted to the situation. However, none of them can explain the innovation forcefully and permanently; all of them present gaps and questions. The innovation is complex, diversified, with a lot of elements interacting, it is difficult to discover the consequences which a fact can offer. (EOI, 2007)

2.6.1. Linear model.

The book (EOI, 2007) explains that it is common to start an innovative process using a linear theoretical model which it is divided into stages. As it has been explained in the process of innovation. The lineal model does not confine itself much to reality, but it has the advantage of having some useful concepts.

Picture 2 Linear Model



Source (Valls and Esorsa, 1998)

This model in stages is useful to reflect a complex reality and to provide a new vocabulary to name and specify the steps which lead to the innovation. This model can give way to the wrong idea that the process must necessarily start with a basic investigation when it does not have to follow the previous sequence. There are innovations which can use existing investigation, or only making the design stage and the launch of the product. This model does not allow to skip steps or start in a forward step. (EOI, 2007)

2.6.2. Marquis Model

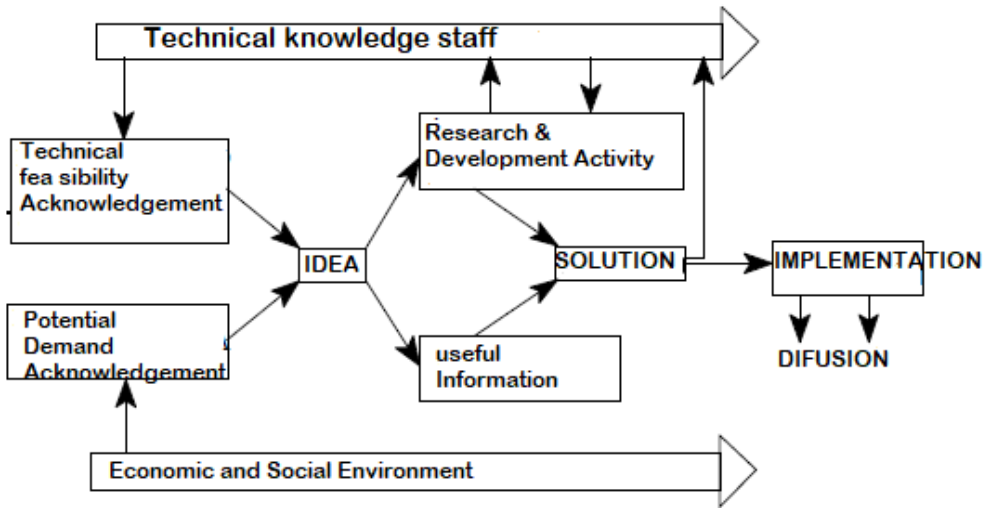
According EOI 2007 this model is more closer to the business reality and it shows that innovations can start with an idea about a new or better product or about an already existing process of production. This idea can come from any department in the company and not only from the research department.

Para cumplirse este modelo debe de ser imprescindible la factibilidad técnica y la demanda potencial. Son necesarios, si falla una no se llegara a la innovación. Muchas investigaciones no suponen una investigación básica o aplicada, ya que son posibles a partir de una combinación de nuevas tecnologías ya existentes. La secuencia del modelo es la que se muestra en la imagen. (EOI, 2007)

So that this model can be achieved it is essential a technical viability and a powerful demand. They are all required so if one fails the innovation will not happen. A lot of innovations does not mean a basic or an applied investigation, since they are possible

from the combination of already existing technologies. The model sequence is the one shown by the picture. (EOI, 2007)

Picture 3 Marquis Model



Source: (Valls and Esorsa, 1998)

This model is divided in 3 stages:

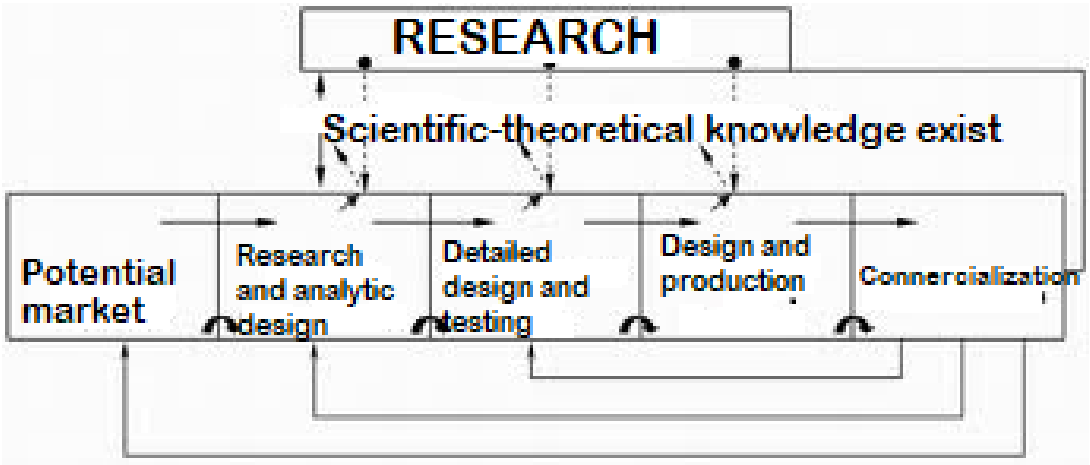
- First it is an idea with a true technical viability and a possible market demand. This idea must be examined according to theoretical knowledges and if there are not enough a process of investigation is required.
- When the problems mentioned before are solved, it is needed to create prototypes or pilot plant which allows to know better the physical properties and the costs of the new products or processes.
- In the final stage, if the results have been positive, the company will deepen more in less important aspects for the innovation of the product or process as it is the design, manufacturing and marketing until it comes the introduction into the market. The costs in this stage are usually much higher that in the fist stage. The creation of a product is not a linear process as it is shown is the provious model. (EOI, 2007)

2.6.3. Kline Model

Este modelo combina los dos anteriores, refleja mejor la complejidad del proceso innovador. Según este modelo existen caminos que llevan a la innovación.

This model combines the previous two, it reflects better the complexity of the innovation process. According to this model there are ways which lead to innovation.

Picture 4 Kline Model



Source: (Valls and Esorsa, 1998)

- The first path is the central, it starts with an idea and an attempt to carry it out and/or an analytical design which must answer the market demands. This task is usually carried out by engineers, the attempt will go through a detailed design process to finish with a prototype, with will be tested in the technological development stage (EOI, 2007)

- This path contains the feedback, each stage of the central path may show failures which force us to make correction on previous stages. (EOI, 2007)

- The third path shows the connection between the research through the use of already acquired knowledges. More research will be needed in the case further information is required to find a solution. (EOI, 2007)

- It shows a connection between research and innovation: discoveries can lead to inventions, these inventions will be called technology push. (EOI, 2007)

2.7. Types of innovation

According to the importance of the innovation it can be classify as a radical innovation or as an incremental innovation.

In an incremental innovation the changes have the purpose of increasing the functionality and the performance of the company, they are an accumulative

succession which taken as a whole can build an important basis for the innovation. They are improvements which take place in the company and industry in a more or less continuous way. In this classification of the innovation the exhaustive processes are not so much developed, on the contrary I+D is the result of the experience gathered by engineers and technicians, about how the user of the products and services may be.

A good example of a company which uses incremental innovation is APPLECOMPUTER. An American IT company founded in 1976 by Steve Jobs and Steve Wozniak when they created their first computer, Apple I, and the company sold 175 computers. At the middle of that same year they started to work in improvements to be introduced in their Apple II, those improvements had to do with weight, the keyword, a smarter design, they were not big changes but improvements. Since APPLE COMPUTER was created it has been introducing incremental innovations, improving its products so as to offer better services to its customers.

Then it is also the radical innovation, this type of innovation means a break with the established things, it can be new products or processes which can not be understood was a natural evolution of the ones already existing. This type of innovation is usually the result of defined I+D processes in laboratories. They are explosive and they break with the status quo.

Among the radical innovations we find TIMEX Company, the product they create are watches, they simplify the number of components and the required operations. This company was a pioneer adding a LCD or LED display screen with an integrated circuit, the printed circuit, quartz crystal and battery to their designs. The company seeks new alternatives in relation with traditional watches, since they introduced the sale of watches in news-stands, small shops. There they could certify their success increasing their sales an 80%. The election of the massive distribution channels was the cornerstone of TIMEX commercial strategy. It is an example of radical innovation in the field of marketing innovation as it generated good results for the company.

The best example and the one which means of the most important innovations of the 20th Century was the invention of the self-propelled vehicle, before this discovery people move around using horses or steam machines.

A more contemporary example would be Netflix Company which has renovated completely the business model of film hiring creating an online film and TV series library. Taking advantage of technology, it develops a platform which allows the users to

download videos and according to the creative destruction, it makes his competence to disappear.

It is clear that the incremental innovations are necessary in any company, the improvements that are obtained are small an they do not add any competitive advantage in the industrial background. When there is an homogeneous competence in the market and this one is not very different, the only way to distinguish is introducing a radical innovation which is totally different to everything that the market offers.

The following table shows the main advantages and disadvantages that a company may encounter when making an innovation.

As it can be seen in the table there are some disadvantages in the radical innovation as the market prediction, the risk and the investment which can be an issue for the company, since the company may invest a lot of money in an innovation which the market may not accept and this way the company will lose income or the risk factor, which refers to invest money in a product or process which then it is impossible to carry out. There are also advantages once the innovation is successful such as the duration and the competitive advantage.

Table **1** incremental vs Radical Innovation

	Incremental	Radical
knowledge	Uses the existent	New Borders
Duration	Short-term	Medium and long-term
Inversion	Low	Moderate, high
Market prediction	High certainty degree	Low certainty degree
Risk	Low, moderate	high
Competitive advantages	Moderate	high

Own creation from Fernando Garcia Gonzalez concepts about innovation

When the market gets to a period when there are not any improvements or incremental innovations this markets gets into a period called standstill period, in this situation the best thing to do is rethink about the product or the process so that it can be done in a radical different way, the reason for this is that the market is an accustomed period which coincides with other companies. It is likely that at first changes in this processes happened very slowly, but those changes can lead to a new technology which improves and surpasses the old technology. This is a technological discontinuity, this means, a transition from a group of products or processes to different ones.

This progress in a new technology which the company has made can be unnoticed by present companies and cause a sudden collapse in the company sales. Business history is full of examples of this type, a good example could be the case of the cash

register machines, the market was at a standstill. The innovation of the electromagnetic cash register machine in 1972 obtained the 90% of the American market which only fell a 10% the year 1976 which the launch of the electronic cash register machines.

Inertia makes important companies not to identify on time the new market tendencies and so they are caught by surprise by smaller companies. A good example is Xerox which did not occupy a niche in the office photocopier market on time and it also fail in noticing that companies needed less and less photocopier machines and more and more printing, because of the peak in the email, moreover, they were delayed in the step from white and black to colour.

When a market is in standstill and a radical innovation appears in the market a new S-curve is produced which allows a company to take advantage of that progress in the long-term, thanks to this innovation the company is able to develop incremental innovations improving the company until the market is in standstill and gets to the end of that curve.

Moreover, when a radical innovation is created this can brings that the company gets into new markets which were impossible to get into before, as it could be the entrance in more economical markets because this new innovation allows the company to reduce costs significantly.

When a company makes a radical innovation this company results in having a competitive advantage among the competence which they did not have previously, as in a standstill period all the companies were in the same situation, but thanks to the radical innovation a company can be ahead in the market reaching a renown in the sector.

3. A HISTORY OF CERAMIC TILES, ITS EVOLUTION:

The history of Ceramic tiles is closely related to the history of the human history, the use of this material is a reflection of their creativity, technological development and their ideas among many perceptions. The ceramic tile can not be only associated to ancient products related to housewares or building and decoration, since currently ceramic has other uses which are more technological and avant-garde such as chips and magnetic materials for computers, medical prothesis, protection of rockets and much more uses.

The word Ceramics comes from the Greek work Keramos, and it includes all the products which are made form boiled clay. The different types of ceramic are a consequence of the different types of clay and mud, of the different types of preparing

and working them, of the oven and temperature, as well as of the treatment of their surfaces with varnish and glaze. The most known products are boiled clay, varnish pottery, chinaware, earthenware, porcelain

The birth of ceramic dates back to the Neolithic time around 6000 BC, one of the most representative discovery in Spain is the pot from Tajos de Cacin.

Picture 5 Hand moulded warp technic

Source: (Montoya, 1997)

In picture 5 it can be seen that it was moulded by hand with the fist technical innovation of warping until it gets its form, then the three handles and the decoration were added. (Montoya, 1997)

According to Montoya (1997) in this time the hand moulding technique was used to make containers with spherical or ovoid forms imitating pumpkins and egg shells and it was even used as as mould to make wicker baskets. Although it is difficult to know when exactly was ceramic invented, what it seems to be real is that its appearance has nothing to do, related to time and place, with the start of farming.

(Montoya 1997) The following innovation in ceramics is the one known as bell-shaped which appeared in the Copper Age from 3000 to 1800 BC. In this time the technique used to reach a shape is still the warping hand moulding. However, the innovation that

is notably perceived is in the degree of perfection referring to the regularity and roundness of the shapes, as well as the metallic finish touch thanks to the final polishing of the item and for the reduced mono boiling, which provides a characteristic dark colour.

Picture 6 Ocoid period

Source: (Montoya, 1997)

The author (Montoya, 1997) states that the following era in this field would be the painted ceramic, which took place in the predynastic Egyptian period or the Nagada culture, IV millennium BC. Ceramic vase characterized by the ovoid period, its light colour and its rich decoration. These vases were produced with a hand-moved potter's wheel.

This innovation coincides with the rise in the ceramic manufacture. The pink colour in the vase is due to the fact that a mixture of clay and calcium carbonate, which was obtained from the limestone colonies which go along the edge of the Nile valley, was used as the raw material to manufacture the vase. (Montoya, 1997)

Picture 7 Predynastic Vase

Source: (Montoya, 1997)

Another important innovation in ceramics would be the votive images in terracotta. Which span from 750 BC to 200 BC. The clearest example of this period is the Ibiza Lady, one of the most important pieces of the Punic art. This type of images appeared with relatively assiduity among funeral objects which have been found in tombs. The manufacturing of the manufacturing of the Ibiza Lady was carried out using a mould and later it was decorated using different technics. First, once the piece was shaped, arms, necklaces and ornaments were added. This type of manufacture provided a rich and varied industry related to the manufacturing of images with a mould which spread along the Mediterranean Sea. Innovation in the mould allowed an easy, fast and serially manufacturing of these images, which produced a trade rise and a huge dissemination of the moulded images and of the moulds, there used to be two types of moulds, of one piece or of two pieces. This rise would bring new and specialised industrial centres. (Montoya, 1997)

The author (Montoya, 1997) explains that between the 550 BC and 100 BC its the funerary ritual ceramic was induced. Using a potter's wheel in the Iberian pottery houses. The use of this tool means a new period in the production of ceramic, since it

did not only allowed to provide a more perfect finishing touch to vases, but also to rise the production and to diversify and standardized their forms.

The industrial ceramic production arrives. From I Century BC to V Century AC a type of ceramic called “terra sigillata” was the dominant one, it characterized by its red or orange colour and by its decoration in relief. It characterized by being a hard and waterproof ceramic, which a especial and beautiful effect caused by its brightness which was reached thanks to a selection of clays, a careful production of its engobe and a perfect control of the different cooking steps. (Montoya, 1997)

To the manufacturing of this type of ceramic with decoration in relief, a clay mould was used with a decoration in negative. One the piece was produced, it was let to dry and then an engobe slay produced with a thin, polished and fluid was applied by by immersion. Then it was stamped at the bottom with the name of the product or the potter who has produced it. After a 900º cooking and a 1100º heat touch, the engobe was synthesize resulting in that special colour, brightness and hardness. The difficult technic used in its production made sigillata ceramic become luxury pottery, but with time it was used as common used pottery. Later different workshops were created in the different provinces of the Empire. (Montoya, 1997)

The metallic reflection pottery innovation. 14th and 15th Century.

The metallic reflection technic was very complex and its results were wonderful. The piece had three cooking processes: the first one, for the spongy: the second one, for the varnish; and the third one for the reflection. The decoration motif in blue are applied before the piece is cooked for the second time. Next a mixture of silver, copper and mercury, iron oxide and sulfur is applied. The third cooking is special, reductive fire, lower temperature and a lot of smoke, made the mixture adhered. Once cooking finished, the piece was rubbed until the rind disappeared and the gold appeared. (Montoya, 1997)

Another important period was the Talavera polychromatic pottery, between 16th and 17th centuries. The technic used was a big fire. Once it was finished and dried the piece was cooked one, when it was already spongy, it was covered by a stanniferous glaze lay and over this lay the decorative motif were drawn, with the stencil or template technic, then they were painted by hand, using different colours and brushes. (Montoya, 1997)

(Montoya, 1997) states that when the drying phase was finished, the second cooking was carried out at higher temperature. This meant the usage of metallic oxide which

could bear those temperature that is the reason why the palette was limited to five colours: blue (cobalt), black (manganese), yellow (antimony), orange (iron oxide) and green (copper oxide)

4. CERAMIC TILES

This section will explain in detail what the ceramic tiles are and their process of manufacturing with the aim of knowing about the product and the process in order to be able to analyze how the inkjet innovation technology has affected the ceramic field worldwide.

Tiles are products with a flat shape which characterized by having not much thickness, the base of the product is formed by different kind of clay and in most cases, the part which will be visible has a vitreous varnish layer. If the product is to cover walls it is called ceramic coating and we will talk about ceramic flooring if the product is produced for the floor.

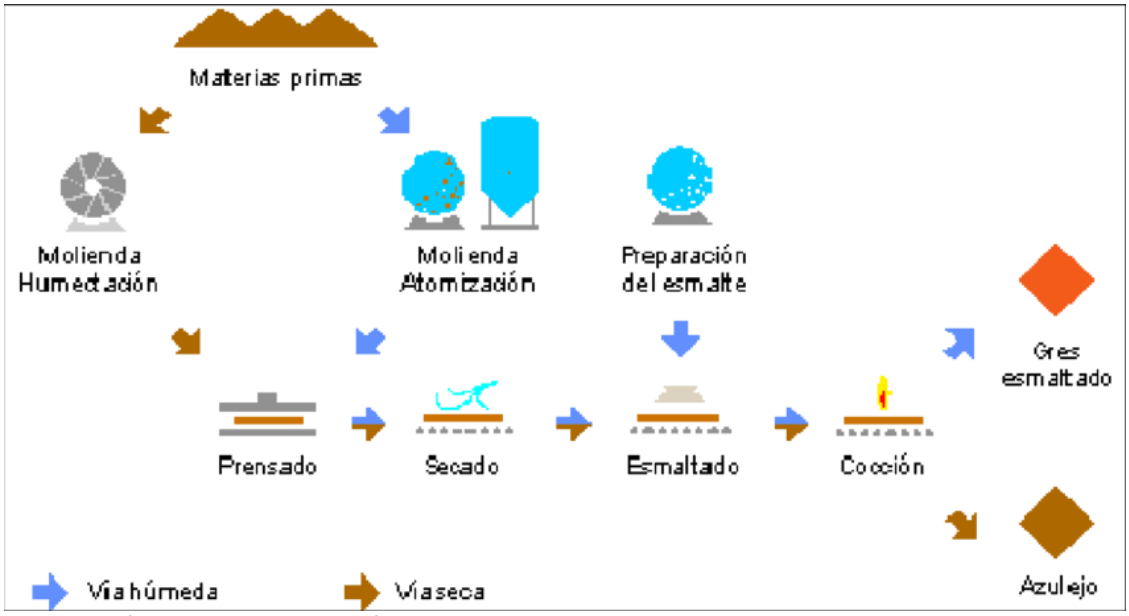
A report from the ministry (Environment, Rural and Marine Ministry, 2011) explains that the process of ceramic manufacturing can be carried out using different methodologies, with a wide range of raw materials and different shapes, sizes and colours. However, the general manufacturing process of the ceramic products is quite uniform, depending on tiles coating or flooring are being manufactured or on if it is home ceramic, bathroom ceramic or technical the manufacturing then will need a cooking process in different stages.

The tile of the manufacturing process develops in some consecutive stages which can be summarize in:

- Raw Materials
- Preparation and Mixture of Raw Materials
- Moulding/forming of products
- Drying
- Superficial Treatment and decoration of ceramic products
- Cooking
- Subsequent processing

In the following image we can we the possibles ways to produce ceramic tiles (ASCER, Manufacturing process of ceramic tiles)

Picture 8 Manufacturing process of ceramic tiles



Source: (anonymous, 2017)

4.1. Raw Materials

As the report (Environment, Rural and Marine Ministry, 2011) states, nowadays ceramic industry uses a wide range of materials due to the variety of products. In the process both natural and synthetic materials are used. Ceramic formula based on clay can consist of one type of clay or a mixture of different clays.

The raw materials used in the traditional ceramic industry are materials extracted directly from the mine or quarry. Their natural origin requires, in most cases, a preliminary equalization which ensures the continuity of their characteristics (ASCER, Manufacturing process of ceramic tiles)

According to the characteristics and stage, the raw materials will be stored outdoors or in warehouses divided in lays, high volume supplier, template warehouses, maturation warehouses or drying warehouses. Those warehouses are equipped with level indicators, overloading valve, filters and gases displacement units so that they expel the air with moved powder. (Environment, Rural and Marine Ministry, 2011)

4.2. Preparation and mixture of raw materials

During the extraction of raw materials the first reduction in size takes place and the initial equalization, that would not be enough and a later preparation is required. Different processes can be used as the pre-drying, pre-mixing, variation from

atmospheric agents/maturation, dry filter treatment/classification by airflow, calcination, material with a synthetic base, frits ans glazes, glaze preparation among others.

Once the raw materials which are going to be used are selected it must be specified the amount of each material that it will be used. Once we have the amount and the materials the preparation of the plaster starts, materials are grind to equalized so that the different materials have similar sizes, this process can be performed by drying or wetting.

4.3. Moulding/forming the objects.

At this point the Ministry report (Environment, Rural and Marine Ministry, 2011) states about mounding, in the past moulding was performed from raw materials in plasto state and during ages this process was performed manually, as it has been mentioned in the history of ceramics. However, currently there are technical specifications which are more are more demanding in the ceramic industry which affects the aesthetic of the product and the final properties.

In the report To mould and form products this is performed through the dry pressing, this pressing is used because pieces must be moulded in flat forms, and this method makes it easier, and because of the small relationship between thickness and surface it is performed dry pressing unidirectionally in simple effect presses, where the preassure which the machine practices at once forms the piece surface. The simplicity of this pressing process allows to reach higher production rate than other pressing methods do. (ASCER, Manufacturing process of ceramic tiles)

The dry pressing is performed through an hydraulic pressing. The modern hydraulic presses can provide a high compaction strength. A lot of presses have electric control units which can check the heigh of the units and adjust the cycle automatically to guarantee a uniformity in size. The hydraulic presses are common in the tile moulding. (Environment, Rural and Marine Ministry, 2011)

4.4. Drying of ceramic products.

Most of clay goods are dried naturally, leaving it at ambient temperature. In a lot of places in Europe this procedure was only possible in the summer. (Environment, Rural and Marine Ministry, 2011)

However, in the modern ceramic industry it is necessary to optimize the drying process referring to speed, thermal efficiency and minimum erosion. There is an exception in products which need soft and slow drying processes, it is necessary to keep an

exhaustive control on the heating speed, the airflow, the temperature and the humidity. The heat for the drying air usually comes form gas burners and from the hot air recovered from the kiln freezing area. That drying air heat can be supply through the cogeneration or another combustible, as coal, biomass, biogas or petroleum coke. (Environment, Rural and Marine Ministry, 2011)

As it is stated in (Environment, Rural and Marine Ministry, 2011) ceramic raw materials vary depending on their dry sensitivity, most of the item that benefit from an initial period of warming in high humidity conditions after the main drying phase where units revive more hot and dry air. Finally, the percentage of water is more difficult to eliminate and it requires of more hot and dry air.

Different kinds of drying have appeared to meet the necessities of the different industrial sectors, in which the nature and the size of the ceramic components vary enormously. (Environment, Rural and Marine Ministry, 2011)

The easier method is hot base drying, it is a method which is becoming obsolete and it is not a mechanical or automatic process. However, it is still appropriate for a slow and soft drying of sanitary ceramics or some refractory products. Some bricks with special shapes are also dried this way. This process consists on the application of heat directly to the lower part of the units in contact with a hot base and through convection currents in an air on that base. The lateral airflow is minimum and all surfaces of the pieces are dried bit by bit, avoiding inappropriate effort during the drying. (Environment, Rural and Marine Ministry, 2011).

4.5. Superficial Treatment and Decoration of Ceramic products.

4.5.1. Textured of clay products

The surface of products made with clay can textured with functional reasons, as an example it is possible to provide an anti slip treatment to covering tiles. (Environment, Rural and Marine Ministry, 2011).

Clay products can be textured with aesthetic motives. Extrusion products can be textured by dragging scratching the surface of the clay column. (Environment, Rural and Marine Ministry, 2011).

4.5.2. Glazing and decoration

As it is mentioned in the report (Environment, Rural and Marine Ministry, 2011). The pieces which come from the drying room are covered by gazing lays in the glazing line. This treatment is performed to confer the surface of the cooked product some technical

and aesthetic properties, such as waterproofing, cleaning ease, brightness, colour, superficial texture, chemical and mechanical resistance.

4.5.3. Gazing, frits and engobes

4.5.3.1. Gazing

A small market for gazing bricks exits, but the most common gazing is in the manufacturing of pavement and ceramic coating. The engobe is used mainly in the manufacturing of clay roof tile and pavement and ceramic coating. (Environment, Rural and Marine Ministry, 2011)

The gazing is prepared with well grind components with watering suspension mainly formed by frits in the case of flooring tiles. The characteristic of suspensions and viscosity are adjusted to the application method such as pulverization, curtain gazing, dry gazing or decorative. Apart from the sanitary ceramic, the green ceramic pieces usually harden through sponging cooking, then according to the components which we apply the gazing with a glassing an uniform lay which can be transparent or dark. (Environment, Rural and Marine Ministry, 2011)

4.5.3.2. Frits

As it is mentioned in (ITC,2011). The manufacturing of frits is a continuous and totally automatized process, the chosen and controlled raw materials, after being rationed and mixed and transported, are introduced in the melting furnace through a worm screw where they are at 100-1600º degrees. At these temperatures the composition melts completely, until it comes out and it is collected at ambient temperature. Because of the thermal crash, there is a break in small fragments of irregular forms, providing the characteristic appearance of broken glass.

The use of frits in the glazing allows among many other characteristics to minimize the toxicity of certain materials, since the frit process allows the inertisation of the composition converting it in glass, without any risk for health or the environment. Another characteristic is that it increases the glazing cooking range, it also provides a glazing higher cooking which will be used in natural raw materials. Finally it gives the glazing a opacity degree and whiteness which can only be obtained with frits (ITC, 2011)

4.5.3.3. Engobe

Because of the chemical nature of the support and glazing, there is usually a lay between them, with an intermediate chemical composition among them. This product is

called engobe, allowing to create an interphase which allows an appropriate coupling between them, it also allows to hide the colour of the support and decorations, another characteristic is that it allows to homogenize and eliminate irregularities of the support to favour future applications, finally it creates a waterproofing lay which avoids problems caused by the support porosity. (ITC, 2011)

4.5.4. Glazing process.

Glazing is performed applying successively, with different technics, the glazing suspensions.

The glazing line is formed by conveyor belts, the ceramic products which come from the dryer room are placed. The equipment required to apply the engobe and glazing are placed along the conveyor belt, both of them are applied in a water suspension, on the raw support with discs (spraying) or belts (continuous curtain) (ITC, 2011)

The spraying technic, as it is explained in (ITC, 2011), is achieve because if the formation of small drops, generated by the turning of a disc or by an injector, which are left on the surface of the ceramic tile, ones next to others, forming a continuous lay. The spray produces thin lays and finishing touches with wrinkled textures and they are usually used in the application of engobe and in the glazing of pavement pieces.

As mentioned in (ITC, 2011) the application of suspensions by continuous curtain technique, after being bombed to the vertical tube which is part of the superior equipment, flows by gravity through its interior. The suspension goes through a container which overflows over the superior surface of the bell, sliding by falling-stream to its edge.

The glazing technique which is the most used in ceramic tiles is the last one because it means finishing touches with smoother textures than the ones obtained through discs or injections that is why it is normally used in the glazing of the tiles, where this characteristic is highly valued. (ITC, 2011)

Once the glazing technique is applied, they become a compact coating of particles, consistent and of uniform thickness, commonly known as consolidated layer. (ITC, 2011)

4.5.5. Decoration Process

The document (ITC, 2011) explains that there are different types of decoration processes which are used in the manufacturing of ceramic tiles, these processes have suffered an important evolution in recent years. On the one hand there is an necessity

to launch into the market new products with aesthetic finishing touches and to improve the competitiveness of the companies, this necessity favors the introduction of new decoration systems. On the other hand, economical factors, which continuously encourage obtaining high quality products at the lower possible costs, have also intervened and have provoked the improvement of the manufacturing systems, of the materials, of the equipment uses to decorate the tiles.

The following systems of decorations of ceramic tiles can be distinguished:

The application of airbrush consists in spraying the tile with a glazing suspension. This spraying can be performed through the action of compressed air, or propelling the suspension through the use of a pump. (ITC, 2011)

4.6. Cooking.

Cooking is an essential process for the manufacturing of ceramic products because it controls a lot of important properties in the finished pieces. Among them are the mechanical resistance, abrasion resistance, dimensional elasticity. Water resistance, and resistance to chemical products and fire resistance.

4.6.1. Physicochemical changes during cooking

The raw materials uses in the ceramic items are usually complex mixtures of clayey minerals, with other mineral substances. The ceramic products with a clay basis are cooked in a kiln, humidity is extracted at between 100 and 200ºC. If ceramic items have organic substances the humidity extracting temperatures would be between 300 and 500ºC. Products which combine water with mineral clayey structures usually extract it at between 500 and 650ºC, while the ones which contain carbonates as calite or dolomite dissociate with the liberation of carbon dioxide at temperatures between 750 and 950ºC

The most important changes which take place during the cooking is the break of the reticular structures of the original clayey minerals, followed by the formation of glassy compounds and vitreous phrases. In order to form vitrification the ceramic products will have to be cooked initially at 900ºC and complete it at 1050ºC.

Non-clayey products, as the refractory ones, also depend on the gases of synthesize, vitrification or re-crystallization, in most cases much higher temperatures are needed in order to obtain the wished properties. The following image shows the cooking temperature for each product.

4.7. Subsequent treatments

Treatments applied to the items when the product is finished, these treatments are divided in mechanical treatments, polishing treatments, carbon enrichment treatment, clinker brick polishing treatment.

Machining: this process can be necessary when producing ceramic pieces whose dimensional tolerance or final shape can not be obtained technically or with enough precision during the primary process.

Another subsequent treatment technique is polishing, this technique is performed specially in porcelain tiles, the cooked surface is polished to obtain a gleaming and homogeneous tile without glazing.

The carbon enrichment is another technique used in the subsequent treatments of ceramic products, this technique is for all the refractory products, must be worked in extremely hostile environments and, for some applications it is necessary to impregnate the cooked pieces with tar from petroleum.

5. CLUSTER IN THE CERAMIC INDUSTRY

A cluster is a concentration of companies, institutions and related agents and located in a near surrounding which compete and also cooperate. Creating a cluster benefits its components because of a better knowledge of the value chain, an ease introducing specialized talent and it allows the best practices to be shared among the cluster components. Also, the coordination of training institutions and specialized research, moreover, the divulgation of technical and business knowledge. Finally, it also has a wide range of suppliers which will allow companies to be able to diversify risks which come from the supplying chain.

From the 80s it has been highlighted the importance of specialized productive gatherings, such as industrial districts or clusters with the main objective of keeping a level of competitiveness and of favouring innovation processes.

Most clusters suffered competitiveness loss during the financial crisis, what may have brought the disappearance of the industrial district. This change can be explained by a growing context of globalization, a higher transmission of people, knowledges and mobility and competence among territories.

The survival of a cluster will depend on its flexibility and capacity that the territory may offer and the industry which it is dedicated to. This will depend on the strategies of the

companies, the technological level and the social capital of the area. If the cluster offers these three characteristics it will be able to avoid its disappearance or relocation of the companies, and reconfigure its global change of value, being able to give way to strong companies in the industry.

The global ceramic industry always presents the same peculiarity which is the territorial organization where a number of auxiliary industry and related organizations are placed in a limited geographical area, such as ceramic manufacturers, ceramic machinery industry and frits and glazing suppliers industry, as well as different public and private industries which give support and contribute to the development of the industry. The development of these sectors called “clusters” have made that this industry has been named by the OECD as medium-low technology, due to the degree in advanced technology innovation. (Albors & Hervás, 2006)

A regional cluster is a group of companies located in a near area, this is called a geographical cluster in equal or related industries. At the same time the industrial districts as the ones formed in Italy are concentrations of companies involved in an interdependent production process, usually in the same industry or segment, which are located in the same area and only separated at most by a distance of an hour journey. The biggest clusters in the ceramic industry are located in Brazil, one in Santa Catarina State and two in Sao Paulo State; one nearer Spain is in Portugal, in Aveido area. In Italy, in the Emilia Romagna Region and finally in Spain, in Castellón. (Albors & Hervás, 2006)

However, the global production of those clusters does not exceeds 30%, the reason why it does not exceeds 30% is the China immersion in the ceramic industry, which means that currently it produces the 70% of the global production. That country has grown thanks to frits and glazing technology which was develped in the ceramic industry in Castellón and the Italian machinery industry. (Albors & Hervás, 2006)

5.1. Ceramic Cluster in Castellón de la Plan.

The ceramic industrial district in Castellon “Cluster” covers the city of Castelló de la Plana and an area with a ratio of 30 kilometers around the city, cities such as Alcora, Borriol, Onda and Nules must be highlighted, in that area it can be found almost the totality of the tile manufacture meaning the 95% of the Spanish tile production, and the 40% of the European and the 10% of the global ceramic production. (Budí, 2008)

Castllón district shows a mature productive system. Especially from the 1980s, it has developed an innovative tendency, an economical growth and a considerable socio

industrial development, also this industry has suffer the financial crisis, affecting it since the year 2008. The most remarkable feature has been the consecutive technological adaptations, which started in the decade of the 1930s y that continued until the 1960s to the big technological step in the year 1980. (Albertos & Salom, 2014)

The mentioned cluster forms a very developed business fabric and combines the high degree in vertical disaggregation of the chain of value with a dense network of business relationships which are both vertical and horizontal and which provide the cluster with an important integration and efficiency. The agents which form the different sectors in the chain of value located in the same geographical area are varied such as raw material suppliers, transport companies, customers, dealers and other ancillary industries. (Albors & Hervás, 2006)

As it is mentioned in the Castellon de la plana ceramic industrial district report (Albertos & Salom, 2014) these are the agents which are present in the local institutional network:

- Business Associations: Spanish Association of Ceramic Tiles and Flooring Manufactures (ASCER); National Association of Ceramics Frits and Glazin, Spanish Association of capital goods for ceramic.
- Professional Associations: Ceramic Technicians Associations (CTA) is very important in providing information and technological knowledge.
- Trade Unions: UGT and CCOO regional delegations.
- Technological Centres, such as the ceramic and Technology Institute (CTI). The CTI was created in 1969 and it is now integrated in Jaume I University in Castellón, whose partners are the most important frits and glazing companies, also the tiling and flooring ones, and it includes as its main functions R+D+i, the commercial and technological dissemination, technical training, testing and trials in laboratories, quality control and certificates and further technical support services.
- Technical college in Jaume I University in Castellón, especially in the chemistry department, and Vocational Training Courses in the Trades and Works School and the Ceramic Superior College in Alcora offers a qualification in Ceramic Technician.

The chain of value starts with the process of purchasing the clay, atomization, preparation of the material, in Castellón district the process is managed in a disintegrated way since the clay atomization process is generically separated from the manufacturer but in the same area, this process allows to have better efficiency, this fact together with the amount of clay present in the area provides globally a selling costs for the ceramic industry in Castellón. (Albors & Hervás, 2006).

In the last few years this district has been one of the most important producer and exporter in the world together with Sassuolo in Italy. During the first years of the financial crisis exports fell a 30%, since 2014 they have been recovering to similar pre crisis values. However, Spain has become the second exporter in the world after China and overtaking Italy.

As it is mentioned in ceramic article in Castellón (Budí, 2008) Spanish industry of ceramic tiling manufacturers can be characterized by being an innovative and dynamic industry, and referring its international positions, it holds a leading place in terms of technological development as well as in design and material and service qualities.

The industry makes a high investment in R+D+i. Currently the industry is making important efforts to consolidate the ceramic product among the opinion leaders. As a result of this effort the use of tiles has grown in non-residential buildings and in other non traditional places such as urban areas and facades (ASCER, Economical Balance of the Spanish Ceramic Intustry in 2014, 2014)

Despite the current difficulties, there is a growth in the global ceramic consumerism and the Spanish tiling industry has already a solid foundation and a future thanks to their global leadership in R+D+i investment and their high degree in internationalization (ASCER, Economical Balance of the Spanish Ceramic Intustry in 2014, 2014)

This economical evolution in a period of crisis is produced thanks to the context of new technological development, especially the digital inkjet printing. This innovation in the ceramic industry has been key to create a market niche in these products market. (Albertos & Salom, 2014)

6. ECONOMICAL ANALYSIS OF THE CERAMIC INDUSTRY IN SPAIN

In order to analyse the ceramic industry we will analyze the following years, 2014, 2015, and 2016 but before this we will mention from 2008 to 2013 in order to show the

crisis that this industry suffered with the objective of highlighting the tendency of the ceramic industry in Spain and in Castellón.

As it is mentioned in the article of the ceramic industrial district of la plana de Castellón (Albertos & Salom, 2014), between the years 2008 and 2012 a severe lost of the productive system has been experienced, losing 27% of the production value and 32% of the employees; however, since 2013 the industry has started to improved. The glazing industry had lost only until 2010, and in 2013 it reached previous levels of production. Despite having lost part of the production system a big number of them still exists nowadays, they are around 200 companies and 13000 employees.

According to figures provided by Spanish Association of Ceramic Tiles and Flooring Manufacturers (ASCER, Economical Balance of the Spanish Ceramic Intustry in 2014, 2014) a light increase in the exportations and national sales has happened. The exportation figures for 2014 reached 2,328.4 million euros, meaning an increase of 4% compared to 2013. The figure reached in 2014 means an increase of the historical maximum which was registered the year before the crisis in 2007 with 2,295 million euros.

Referring to the exportations in 2014 they were made to 186 countries and it reached 2,328.4 million euros, meaning a 4% increase compared to 2013. (ASCER, Economical Balance of the Spanish Ceramic Industry in 2014, 2014)

In the report (ASCER, Economical Balance of the Spanish Ceramic Industry in 2014, 2014) the total invoice which the ceramic industry gained meant a 3.8% increase, referring to the national market it must be highlighted that the tendency was a decreasing one but this year is has suffered a light increase of 3%.

In 2014 Ceramic product was the first European product and the second exported in the whole world. Referring to the industrial sector this is the third with a higher commercial surplus in Spain and the first referring to commercial cover. (ASCER, Economical Balance of the Spanish Ceramic Industry in 2014, 2014)

Spanish production of ceramic tiles and flooring is estimated to have been 425 million m2.

Next we will analyze the ceramic figures from year 2015, it can be highlighted that during that year there was an increase in the percentage, increasing a 6% with respect to the year 2014 whose increased was two points lower. The number which the industry reached was 3,075 million euros. As the recuperation in the economy moves

forward, the consumerism will grow, which is the boost the industry needs. (ASCER, Economical Balanced of the industry in 2015, 2015)

Referring to the exportations in 2015 they increased a 4,5% reaching the number of 2,445 million euros. The principal destinations have been: France, Saudi Arabia, United Kingdom, the USA and Algeria. (ASCER, Economical Balanced of the industry in 2015, 2015)

If we divide the exportation in areas in the European Union it grew a 37,2% and this shows the recovery with a global growth of 12,2%, it must be highlighted the evolution in the United Kingdom where exportations meant a 21%. Another increase which should be highlighted is the exportation to a non European Union countries, the USA, in the year 2015 exportations to that country meant a 40% increase, showing a positive evolution for the ceramic industry. (ASCER, Economical Balanced of the industry in 2015, 2015)

Regarding the national market it becomes steady and it starts to grow with an 11,9% increase. Which means reaching the number of 630 million euros. It must be considered that the number is low and that currently the domestic market is only the 20% of the total income. (ASCER, Economical Balance of the industry in 2015, 2015)

In relation to the Spanish production of ceramic tiles and flooring it is estimated that it grew a moderate 3% producing 437m2.

Finally the analysis of the year 2016, official figures does not exist for this year so far but estimation does exist. A light growth in the exportations and domestic sales. Totally growing a 7% to reach the number of 3,316 million euros. (ASCER, Economical Balance in the Spanish ceramic industry in 2016, 2016)

Regarding exportations a deceleration was produced especially during the second term. This year the growth was a 4,8% while in 2015 the growth was 6% that is the reason of the deceleration. Despite this deceleration exportations meant an income for the industry of 2,570 million euros. The growth is maintained thanks to the evolution in the sales with an increase of 10,3% in the European Union and of 28% in the USA. (ASCER, Economical Balance in the Spanish ceramic industry in 2016, 2016)

In the national market it means an increase of around the 16% reaching around 746 million euros. The growths are relatively high since we depart from a very low levels. (ASCER, Economical Balance in the Spanish ceramic industry in 2016, 2016)

Ceramic tiles and flooring production has grown around 11,8%

After analyzing the ceramic industrial sector it can been observed that there is a growing tendency in both exportations and the national market. In the year 2014 this industry was already in the same numbers as before the crisis started in the year 2007. Year 2015 and 2016 meant a bigger increase regarding economic figures

As a negative side for the ceramic industry, the national sales must be highlighted because they represent a small percentage compared to exportations to other countries.

As positives sides, the increase in exportations, to the European Union as well as to the USA should be highlighted. Also the stability of the industry and its constant growth.

7. INKJET TECHNOLOGY

The inkjet technology was launched in the 1970s as a printing system in marking and codifying products, Hewlett Packard commercialized the first inkjet printers. Since then a constant evolution has happened being able to develop this technology for printing on different materials, not only on paper.

The inkjet printing methodology is a suitable methodology for the functional printing, since printing process is made without any contact with the support. This way it is possible to print on very sensitive materials such as printing on solar panels or ceramic products. Another positive aspect of the inkjet technology is that it allows to print a uniform coat and to control in an appropriate way the thickness of the coating. (Interempresas, 2010)

According to the report on polymer printing technology (Hoyos, 2013), this technology has brought important commercial successes in the ink-jet printing, which include high speed product codification and marking, mail addressing, big format graphics both indoors and outdoors ones. The mentioned technology has also become an industrial application mainly in the field of textile, ceramic and food printing. The following table shows evolution in this area.

Table 2 Inkjet

Application	Benefits of the ink jet
Automobile coating	Powdered or immersion, replacement, reducing waste and increasing the coating uniformity.
Decoration in plastics	Printing quality improved compared to serigraphy. Fast creation of prototypes and a wide range of designs.
Conductive Structures	Short production time. Minimize the quantity of waste products.
3D Prototypes	Fast design of 3D structures using computing programs
Variable Information	It allows fast exchange of information in printing compared to the analogue printing which demands a new hardware development.
Ceramics	Minimize the preparation time, eliminating time in the inventory control.

Information from (Hoyos, 2013)

7.1. Inkjet implementation with respect to precedent technology

Until the year 1994 the decoration process which the ceramic companies used to use where the serigraphy technology. In this process pigments passed to the ceramic piece previously glazed through the xerographic screens which covered the colour spectrum, this process required of a constant creation of different screen sets for each decorative system and their replacement due to overuse. Another negative aspect is that large series should be manufactured so this meant a big amount of stock, the reason was that if the same tone colour was demanded it was very difficult to repeat the same tone in decorations because of the interaction between glazings and pigments.

That same year System, an Italian company launched to the market the Rotocolor machine which allowed to replace the screens by printing rollers which provided the basic colours to the tile. This technique meant an improvement for this industry, but it required the electronic printing of the rollers, which also get spoilt after being used for a particular number of square metres. This technology also had the negative aspect of being in contact with the decorative support, producing breaks of the pieces, the impossibility of decorating with reliefs or the curved extreme of the pieces among other negative aspects.

According to the report of manufacturing processes of ceramic tiles (ITC,2011), there is another technique which is the photogravure technique which consists on the use of a roller in whose surface some holes have been done through a laser printing system, as a whole they create the desired image on the tile. The diameter and the depth of the holes are determined the moment of their recording. As the holes are created by laser they are smaller than the ones obtained photographically in the serigraphy screen, for this reason the images have a better definition.

Despite the effort made by flooring manufacturers to purchase this technology, the ink flow technology has been relegated exclusively to the manufacturing of pieces which are extremely difficult or impossible to produce using traditional methods because of their characteristics. (Coleres Ceramicos S.A & Talleres foro, S.L., 2010)

Currently, there is not doubt that the ink flow technology, has become one of the most used when there is a need in printing digital images, having replaced to any other digital technology such as the sublimation printing and the digital xerography. This technology is the one which is being most developed and spread in new sectors.

According to the report of Kera-eco Vehicles for ceramic decoration (Díez, 2013), inkjet technology has meant a truly revolution for the ceramic industry, both nationally and internationally, devastating other techniques such as serigraphy or photogravure, these two techniques were present in the ceramic industry before the inkjet. Although the first inkjet machine was developed in the year 2001, the growth in the use of these machines has really increased since the year 2011 when they went 538 machines to 1422, meaning a growth of 160%.

Currently more than 1600 printers are installed all around the world, reaching important levels of implementation, in Spain and Italy inkjet machines prevail with 80% of implementation, in China it is 50%, while other areas where the implementation started later they have 10 to 15% implementation, for this reason it can be foreseen that these areas will suffer an important growth in the next years.

According to (Díez, 2013) inkjet technology implementation is still far for reaching the levels of decorating machines which use serigraphy and photogravure.

7.2. History of the creation of the inkjet for ceramics

The article about Digital Glazing for totally digital glazing and decoration process (Esmalglass-itaca grupo, 2011), innovation on digital printing technology through ink flow 'inkjet' meant one of the most important milestone in innovation in the history of the flat industrial ceramic. After the appearance of the single-deck roller kilns and the important appearance of the decoration system by photogravure.

The year 200 was when the innovation appeared for the first time with the prototype of an industrial machine for the ceramic industry, the first machine to decorate tiles with ink flow was created by the company Kerajet, that machine has been awarded because it was a global innovation in digital printing technology by ink flow or 'inkjet' which has been considered as a radical innovation in the ceramic industry. This technology

allowed the company to be a pioneer in the whole world and to entry into a huge market and a business field for the entire industry, since its invention.

The innovation process of this technology started some years before, in 1997 the company started to make tests printing tiles, they created a first prototype in 1998 Jose Vicente Tomás, an electronic engineer form Polytechnic University in Valencia and with a wide experience in the ceramic industry, together with Antonio Queros, graduated in Chemistry by Valencia University and a technician in the company Ferrol enamel Española S.A., started to develop new possibilities for decorating in the ceramic process based on digital technologies, in 1999, they received financial support from the center for the industrial technological development (CDTI), they dealt with an initial prototype in a project led by Ferro Enamel Española SA. This prototype was later developed by Kerajet SA and it was based on printheads system and the control hardware, the development of a design software and its transmission, and the injection mechanism. The request for a patent was also difficult PCT. (Hidalgo, y others, 2010)

The same year Kerajet SA was established with Ferrol Enamel Española SA, Enginyeria PC and Rafael Vicent Abella a colleague of Jose Vicente Tomás. Kerajet dealt with the electronic devices and the software applications and the decorating machinery while the company Ferro Enamel Española SA was in charge of the ink development. (Hidalgo, and others, 2010)

The creation of this technology became a milestone in the history of the ceramic industry, and it meant an innovation which helped the ceramic tile flooring and covering manufacturer to improve their position in the market with a distinguishing product, which allows the manufacturer to have more productive and flexible plants without raising costs, also it helps to have a better storehouse management, to be able to face the production of small lots and to personalize the products. Making it possible for the company to develop strategies about the business aspect which they are more interested in. (Esmalglass-itaca grupo, 2011)

Since the ink flow printing technology became a reality constant evolutions have been taking place such as the continuous development of printheads, electronic newnesses, software and the continuous development in inks has allowed a deep consolidation of this technology in the ceramic industry. Apart from this evolutions produced it must be highlighted two big periods in that period. The first one happened in 2006 approximately when inkjet technology for ceramic products only worked with soluble ink. During this period only a few units were installed since it had big limitations, related with chromatic aspects, the reason for this was that the soluble ink used limited the

possibility to make products because of its little chromaticity, instability and even costs. From this moment, the introduction of pigmented ink meant an important qualitative leap. Inkjet printers were able to work with sets of pigmented ink and to print a great part of the regular chromatic space to which the industry is used to and also the costs are very competitive. This leap was amplified if possible with the entrance of new components in a competitive scene, new machinery manufacturer and new dye industry, a big amount of companies directed to provide the ceramic industry with an optimal solution. (Esmalglass-itaca grupo, 2011)

7.3. How does the ink stream works.

In the report of Ceramic tiles manufacturing process (ASCER). This process is based on making the ink go through a filter with a small diameter, which sprays it, making a stream of small drops which need to reach the substratum and draw a picture on it. This technology differentiates among others techniques because it diverts these drops in a way that they impact on the substratum in different parts to create the wished drawing. This process can be combined with the movement of this substratum allowing to obtain more complex decorations.

The ink stream system is based on the use of four inks which are cyan, magenta, yellow and black, that together with the electronic process of image transference allows to decorate the piece with the wished motives and tones. (ASCER, Ceramic tiles manufacturing process, 2003)

The piece printing is carried out without the necessity of stopping the piece without being in contact with the item, what will allow the total decoration of the piece, even acquiring reliefs. (ASCER, Ceramic tiles manufacturing process, 2003)

All the printing stages are performed electronically, therefore it is possible to carry out the necessary adjustments in a fast way without the necessity of new inks or screens. (ASCER, Ceramic tiles manufacturing process, 2003)

7.3.1. Ink stream technology

In the ink stream technology two types of technological families can be found, we can distinguish between the continuous ink stream or the drop down ink stream. The continuous stream expels the ink drops through a piezoelectric system (it is explained later) in a continuous way, in a unique stream while the device is on. However, the demanding drop down technology, this system works shooting the required drops to create an image. (Jiménez, 2017)

7.3.1.1. Continuous stream

In the continuous stream family we find the technique which it is used for the ceramics, this technique is named multiple deflection. This technology allows to generate a continuing identical drops which its journey to the substratum, are derived depending on the correct position in the coverage area. The image is built by the synchronize actions of the multiple intakes.

The process in this technology is divided in three parts, the first one is the drop formation, an ink stream will be applied at the intake exit a periodic perturbation in order to make the stream into a continuing sequence of identical drops.

In the second part, an electric charge is induced on each drop so that in the last step, named deflection, causes a transversal displacement of each drops depending on the electric charge. Those drops which do not have to reach the substratum are derived to the to the position of a suction hole and redirected to the circuit. (Coleres Ceramicos S.A & Talleres foro, S.L., 2010)

This technology has been an important development for the tile digital printing, no only from the point of view of the new products that can be developed with this technique, also the manufacturing of traditional products according to sustainable manufacturing premises. (Coleres Ceramicos S.A & Talleres foro, S.L., 2010)

7.3.1.2. Drops on demand

On the other hand, the family drop on demand uses the piezoelectric technique, the process is a change in the volume of the injector cavity which is produced from the piezoelectric strength making the flexible material to deform which makes the drop to be ejected. (Jiménez, 2017)

The operating system is line by line although it is common that different lines print at the same time. The printhead resorts a horizontal strip of the work and inject the ink if this is required by the task. (Jiménez, 2017)

The piezoelectric is a property which certain materials have, when they are submitted to an electric field they deform under internal action strengths. The produced is normally reversible, therefore when crystals are not submitted to an external voltage or electric field anymore, their recover their form. Effected required for the generation of the following drop. (Jiménez, 2017)

Another technique is the electrostatic process, in this case a new electric field is generated between the printing prinhead and the printing support, through alterations which depend on the image in the ink stream injector system.

Changes in the electric field make the drop liberate. Changes in the electric field can be provoked with electric signs or with thermal energy. (Jiménez, 2017)

8. CONCLUSION

In the history of ceramics improvement has appeared constantly, ceramics started being only used to make vases, currently it has a lot of different uses, from making vases as it was its firs use, to make dental implant or computing chips, these progresses have allowed ceramics to entry into many different markets and they can be improvement in the materials or technical improvements with of the purpose of being able to develop products with better qualities or reduce their costs.

The Ceramic Spanish industry has been in pursuit of new market where to set their products and to adapt to the market new requirement nationally as well as internationally. The existence of a cluster in Castellón area, which is consolidated and which represents 95% of the Spanish production, 40% of the european production and 10% of the global production, has allowed the creation of organisms to create innovations and obtain competitive advantages in the ceramic market.

This process of innovation which exists in the cluster in Castellón has partly been thanks to the creation of the Ceramic Technological Institute (CTI), this institute provides the possibility to small and medium companies which do not have their own resources of obtaining new competitive advantages.

The Spanish economic crisis affected directly to the production, because the crisis struck mainly the building industry and being this one a powerful market for the cluster in Castellón before the crisis. Because of the crisis the cluster lost 27% of the production, in 2013 the recovering started, this recovering had nothing to do with the national market for the first years, the national demand is growing bit by bit, but exportations have increased a lot since 2013, in 2014 exportations reached their historic high, its principal customers are countries such as France, Saudi Arabia, United Kingdom, the USA, and Algeria. The data offered by ASCER, show that currently the national market is recovering since it grew around 16% in 2016, also exportations are in constant growth.

The development of the inkjet technology for ceramics has allowed to replace preceding technolgy, such as serigraphy, this technology used xerographic screen which covered the color spectrum, this process required the constant change of the screens due to their overused, another negative aspect was that large lots were needed to be manufactured and therefore large storehouses were required.

Another machine which was developed was the rotocolor, which used engraved rollers, this technique meant an improvement regarding the previous one but also the rollers eroded in contact with the piece and there was a possibility of breaking the piece and some kinds of relives were impossible to decorate.

Ultimately and innovation which does compete with the inkjet technique is the rotogravure, which uses the laser printing, the diameter and the holes are smaller than with the serigraphy screen, but because of its characteristic it is an excessively complicated technique or impossible to produce using traditional methods.

Comparing the last one with the inkjet technique the first one would be better uses only in a few circumstances.

To finish the inkjet printing or ink stream technology, the process is to make the ink go through a filter allowing it to create the wished drawing, it only has four inks which are cyan, magenta, yellow and black, the production of the pieces takes place without stopping the piece and allowing to do reliefs. This technology allows not to have to constantly remove templates or rollers, saving materials since no pieces will be broken as the rollers are not in contact with the piece, and overall the advantages it has is the small lots and quantities can be produced covering this way the customers demands.

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